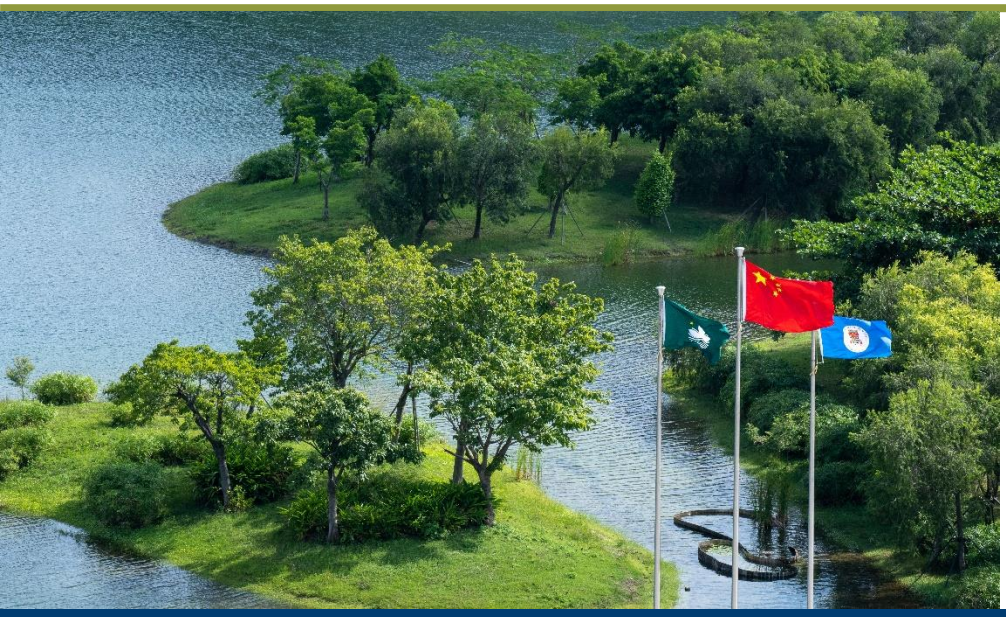
澳門大學
UNIVERSIDADE DE MACAU
UNIVERSITY OF MACAU

應用物理及材料工程研究院
INSTITUTO DE FÍSICA APLICADA E ENGENHARIA DE MATERIAIS
INSTITUTE OF APPLIED PHYSICS AND MATERIALS ENGINEERING

IAPME Newsletter

https://iapme.um.edu.mo/



ISSUE 16

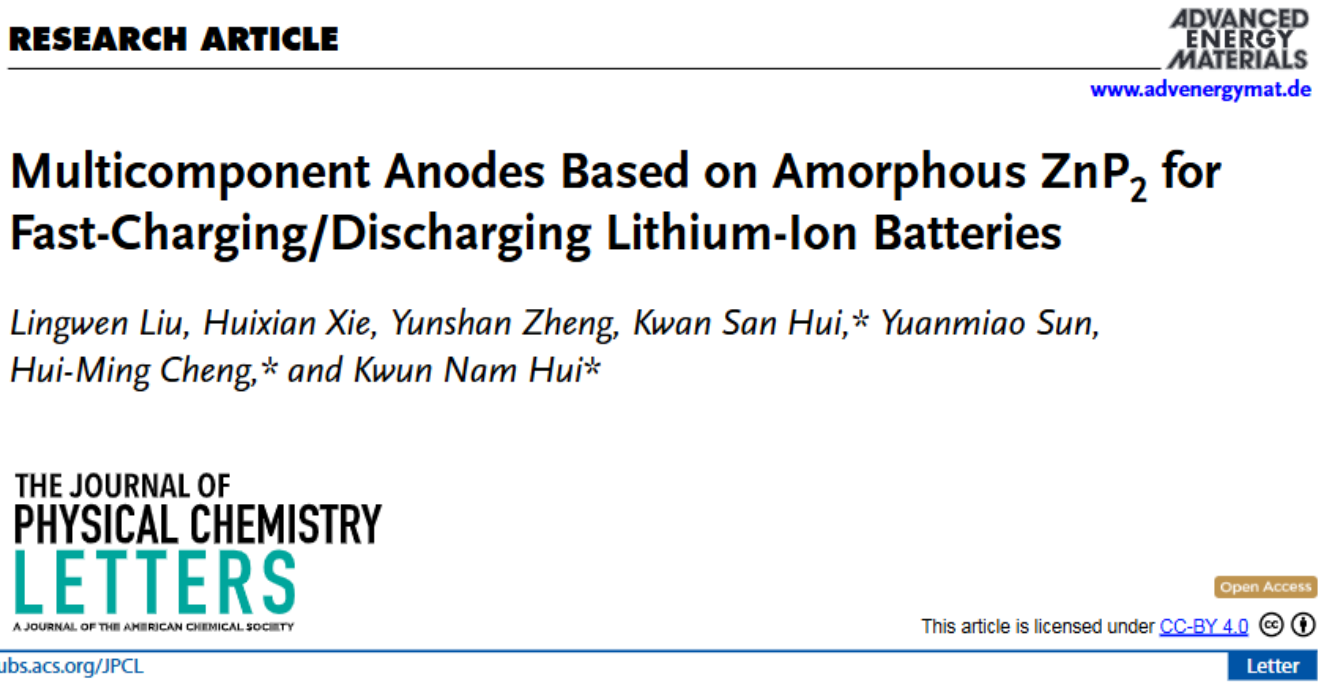
08 January 2025

✧ Content

❖ Publications (*corresponding author)

1. **Lingwen Liu**, Huixian Xie, Yunshan Zheng, Kwan San Hui*, Yuanmiao Sun, Hui-Ming Cheng*, and **Kwun Nam Hui***, "Multicomponent Anodes Based on Amorphous ZnP_2 for Fast-Charging/Discharging Lithium-Ion Batteries", *Advanced Energy Materials*, 2404900 (2024). DOI: 10.1002/aenm.202404900. [2023 IF=24.4]

2. **Ting Ding**, Yinman Song, Mengwei Wang, Hang Liu, Jing Jiang, Jincheng Xu, **Hongchao Liu***, **Kar Wei Ng*** and **Shuangpeng Wang***. Atomic Layer-Deposited Silane Coupling Agent for Interface Passivation of Quantum Dot Light-Emitting Diodes. *The Journal of Physical Chemistry Letters*, 15 (36), 9233-9238 (2024). DOI: 10.1021/acs.jpclett.4c01974. [2023 IF=4.9], Nature Index Journal



RESEARCH ARTICLE

ADVANCED ENERGY MATERIALS
www.advenergymat.de

Multicomponent Anodes Based on Amorphous ZnP_2 for Fast-Charging/Discharging Lithium-Ion Batteries

Lingwen Liu, Huixian Xie, Yunshan Zheng, Kwan San Hui, Yuanmiao Sun, Hui-Ming Cheng,* and Kwun Nam Hui**

THE JOURNAL OF PHYSICAL CHEMISTRY LETTERS
A JOURNAL OF THE AMERICAN CHEMICAL SOCIETY

Open Access
This article is licensed under CC-BY 4.0

pubs.acs.org/JPCL

Letter

Atomic Layer-Deposited Silane Coupling Agent for Interface Passivation of Quantum Dot Light-Emitting Diodes

Ting Ding, Yin-Man Song, Meng-Wei Wang, Hang Liu, Jing Jiang, Jin-Cheng Xu, Hong-Chao Liu,* Kar-Wei Ng,* and Shuang-Peng Wang*

澳門大學
UNIVERSIDADE DE MACAU
UNIVERSITY OF MACAU

應用物理及材料工程研究院
INSTITUTO DE FÍSICA APLICADA E ENGENHARIA DE MATERIAIS
INSTITUTE OF APPLIED PHYSICS AND MATERIALS ENGINEERING

IAPME Newsletter

ISSUE 16

08 January 2025

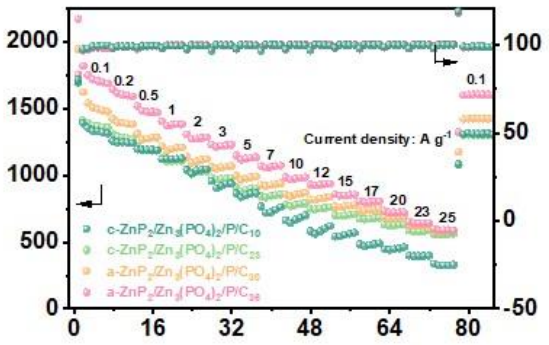
❖ Research Stories

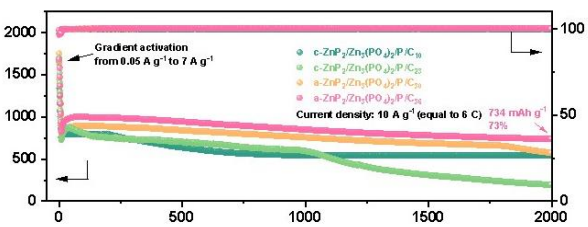
The UM research team has achieved a significant milestone by integrating amorphous ZnP_2 hybrids into lithium-ion batteries for rapid charging

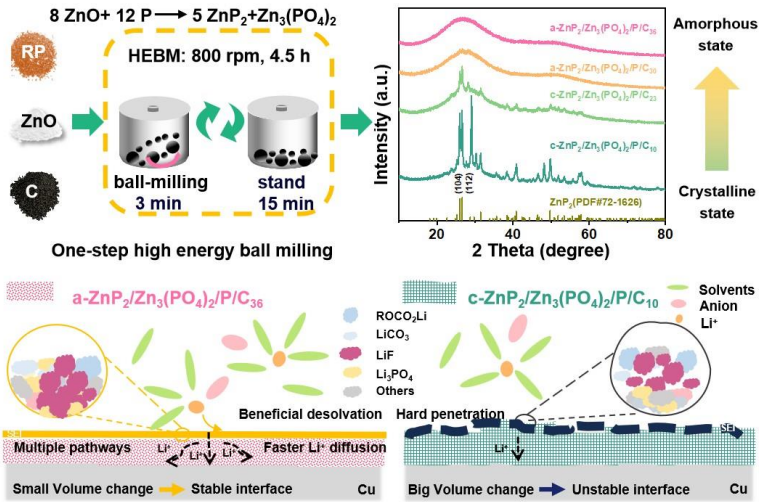
- This work aims to facilitate large-scale, cost-effective synthesis and evaluate the potential of the hybrid amorphous ZnP_2 as a high-performance anode for fast-charging/discharging lithium-ion batteries. The porous structure and isotropic nature of hybrid amorphous material improve Li^+ accessibility, reaction kinetics, LiF/Li_3PO_4-rich SEI, and structural stability during fast lithiation/delithiation with high-rate and long-term cycling superiority.

(from left) Ms. Lingwen Liu and Prof. Kwun Nam Hui

- As a result, $a\text{-}ZnP_2/Zn_3(PO_4)_2/P/C_{36}$ electrode demonstrate significantly improved capacity (1648 mAh g^{-1} at 0.1 A g^{-1}, 980 mAh g^{-1} at 10 A g^{-1} and 583 mAh g^{-1} at 25 A g^{-1}) and long-cycle stability (0.0035% capacity delay rate within 2200 cycles at 5 A g^{-1}/3 C, 0.0135% capacity delay rate within 2000 cycles at 10 A g^{-1}/6 C, and 0.0137% capacity delay rate within 2700 cycles at 20 A g^{-1}/12 C).







Lingwen Liu, Huixian Xie, Yunshan Zheng, Kwan San Hui*, Yuanmiao Sun, Hui-Ming Cheng*, and **Kwun Nam Hui***, "Multicomponent Anodes Based on Amorphous ZnP_2 for Fast-Charging/Discharging Lithium-Ion Batteries", *Advanced Energy Materials*, 2404900 (2024). DOI: 10.1002/aenm.202404900. [2023 IF=24.4]

Prof. Kwun Nam Hui is the corresponding author of this study. The first author is Ms. Lingwen Liu, Ph.D. student in IAPME. This work was supported by the Science and Technology Development Fund, Macau SAR (File no. 0046/2019/AFJ, 0007/2021/AGJ, 0070/2023/AFJ, 0022/2023/RIB1, 0033/2023/ITP1, 0032/2021/ITP, and 006/2022/ALC), University of Macau (File no. MYRG2022-00223-IAPME and MYRG-GRG2024-00166-IAPME).

❖ Research Stories

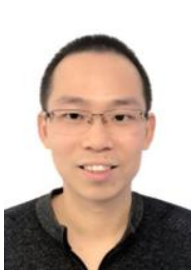
UM research team developed a low-temperature adsorption-based strategy for effective interfacial modification of QLEDs

- Solution-processed quantum dot light-emitting diodes (QLEDs) are considered a promising candidate for the next generation display technology due to their high color purity, wide color gamut, and low power consumption. Inserting an insulating layer between the charge transport layer (CTL) and quantum dot emitting layer (QDL) is widely used in improving the performance of QLEDs. However, the additional layer inevitably leads to energy loss and joule heat.

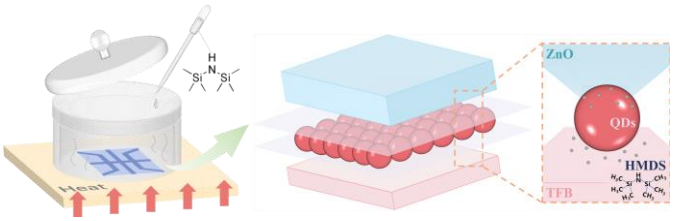
- Drawing inspiration from atomic layer deposition (ALD), an ultra-thin single-layer silane coupling agent is used to passivate the interface between the QDL and CTLs. Because the ultra-thin layers induce negligible series resistance to the device, they can partially passivate the interfacial defects on the electron transport side, and help confine the electrons within the QDL on the hole transport side. These interfacial modifications can not only suppress the non-radiative recombination but also slow down the aging of the hole transport layer, leading to an 8% enhancement in the device current efficiency and a 50% boost in operation lifetime.

- The team underlines a low-temperature adsorption-based strategy for the effective modification of interfaces in not only QLED structures, but also any layer-by-layer device architecture with low fabrication thermal budget.

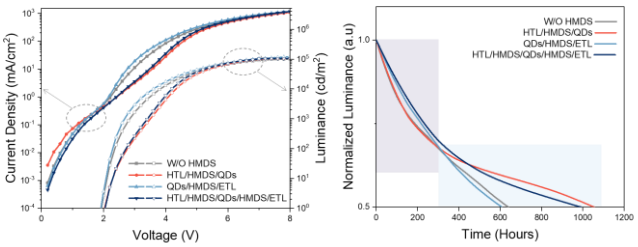

(From left) Ms. Ting Ding and Prof. Shuangpeng Wang

(From left) Prof. Kar Wei Ng and Prof. Hongchao Liu



The substrates coated with different underlying layers are placed in an airtight container along with a droplet of silane coupling agent HMDS. Device structure: ITO/PEDOT: PSS/TFB/(HMDS) /QDs/(HMDS)/ZnO/Al.



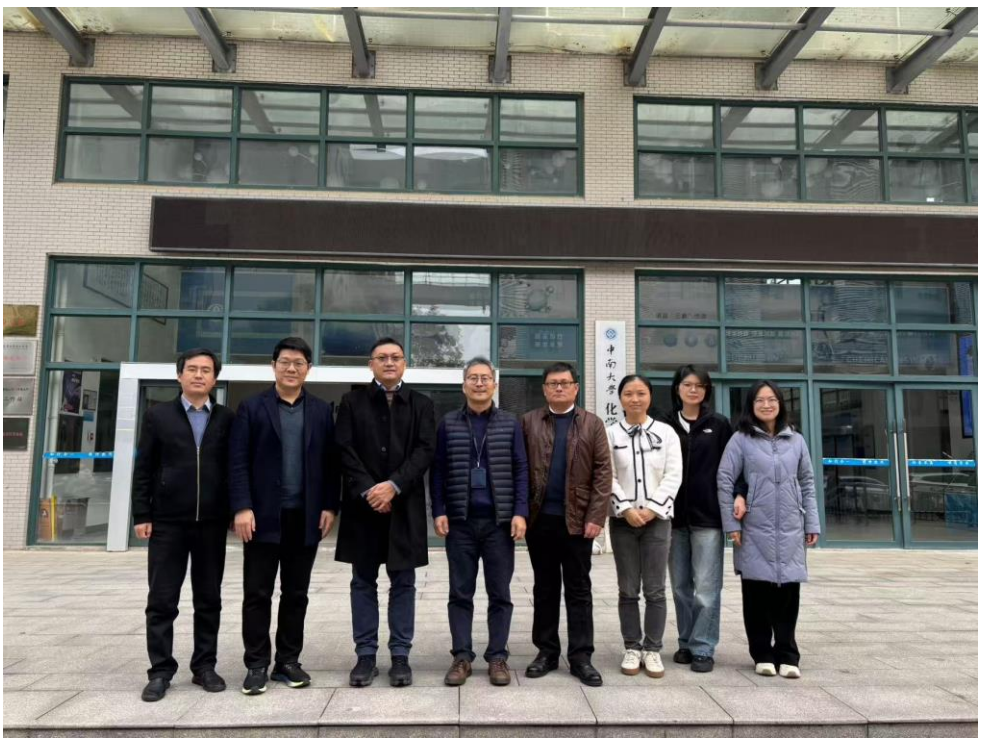
Ting Ding, Yinman Song, Mengwei Wang, Hang Liu, Jing Jiang, Jincheng Xu, **Hongchao Liu***, **Kar Wei Ng*** and **Shuangpeng Wang***. Atomic Layer-Deposited Silane Coupling Agent for Interface Passivation of Quantum Dot Light-Emitting Diodes. *Journal of Physical Chemistry Letters*, 15 (36), 9233-9238 (2024).
DOI: 10.1021/acs.jpclett.4c01974. [2023 IF=4.9], Nature Index Journal

Prof. Shuangpeng Wang, Prof. Kar Wei Ng and Prof. Hongchao Liu are the corresponding authors of this study. The first author is Ms. Ting Ding, Ph.D. student in IAPME.

❖ IAPME Professors Visited Central South University

As invited by Prof. Xiaobo Ji, Vice Dean of the College of Chemistry and Chemical Engineering, and Prof. Libao Chen, Distinguished Professor from the State Key Laboratory of Power Metallurgy at Central South University, three representatives from IAPME, Prof. Kwun Nam Hui, Prof. Haifeng Li and Prof. Qing Li, visited Central South University from December 12 to 14, 2024.

During their visit, representatives from two institutions, the School of Chemistry and Chemical Engineering and the Power Metallurgy Research Institute of Central South University, as well as the University of Macau (UM), delivered presentations. The representatives from UM began the doctoral recruitment presentations by introducing the UM and its campus in the Guangdong-Macao In-Depth Cooperation Zone in Hengqin, highlighting its geographical advantages. They then outlined UM's doctoral programme, including admission policies, training plans, and research directions. Additionally, they explained the application process for UM's doctoral programme, detailing the requirements, available scholarships, and the application website.



The UM representatives also delivered six individual presentations on their research in materials science and battery technology. These presentations not only attracted outstanding students interested in engaging with cutting-edge scientific research but also strengthened collaborative ties in related scientific fields between the two universities.

Finally, the representatives extended a warm invitation to potential PhD candidates from Central South University to explore research opportunities at UM.

Prof. Haifeng Li from IAPME presented two seminars at Central South University, focusing on the application of neutron scattering in solid-state battery research. The seminar explored the critical role of neutron scattering, a non-destructive and highly penetrative technique, in uncovering the internal mechanisms of solid-state batteries. A significant portion of the discussion highlighted the NASICON structure, a promising solid-state electrolyte celebrated for its high ionic conductivity and chemical stability. As a widely studied material, NASICON plays a pivotal role in advancing energy storage solutions.

To gain deeper insights into NASICON's structural and functional properties, the seminar delved into various neutron-based characterization techniques, including elastic neutron diffraction and pair distribution function (PDF) analysis, to study solid-state electrolyte structures and ion transport mechanisms. These methods provide unparalleled insights into the microstructural and dynamic properties of materials, enabling researchers to address challenges in battery performance and stability.

One of the seminar's highlights was the presentation of recent in-situ time-of-flight neutron diffraction studies on NASICON. The research identified a critical phase transition temperature of 470K, revealing a strong correlation between this phase transition and the material's ionic conductivity. These findings highlight the relationship between structural changes, phase transitions, and NASICON's optimal performance, offering a roadmap for advanced doping strategies and the development of high-performance solid-state batteries. This underscores the importance of tailoring material properties to meet specific performance requirements.

Beyond the technical aspects, the seminar emphasized the importance of collaboration and resources. Interdisciplinary collaboration and access to advanced facilities, such as the China Spallation Neutron Source (CSNS), were highlighted as critical to solving complex energy storage challenges. Researchers and students were encouraged to leverage these facilities to further their investigations into solid-state battery materials.

In addition to advancing scientific understanding, the seminar also served as a platform to promote talent recruitment. Opportunities for doctoral and postdoctoral positions at the University of Macau were introduced, targeting candidates with expertise in physics, materials science, chemistry, and related fields. This initiative aims to attract top talent to further research in cutting-edge energy storage technologies.

This seminar demonstrated the transformative potential of neutron scattering in advancing solid-state battery technologies, particularly for materials like NASICON. By offering detailed insights into light element behavior, complex structural changes, and dynamic processes, neutron scattering has proven to be an indispensable tool for developing the next generation of energy storage systems.

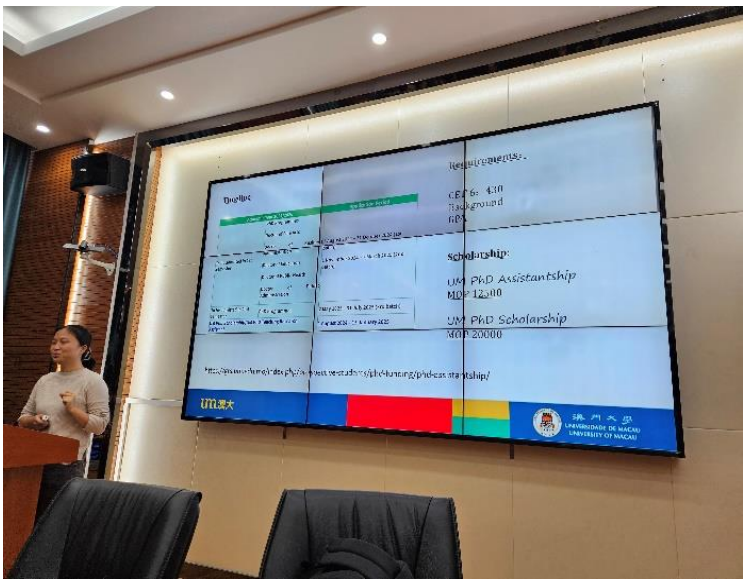
Looking ahead, the findings presented in the seminar are expected to inspire further research into interface studies, long-term cycle stability, and material optimization. Collaborative efforts between Central South University, the University of Macau, and other institutions are anticipated to accelerate the commercialization of high-performance solid-state batteries, contributing to global efforts to achieve carbon neutrality goals.

In a subsequent research seminar titled "Advances in Potassium-ion Batteries: Materials Design and Solid Electrolyte Interface Analysis," Prof. Kwun Nam Hui delved into the background and significance of potassium-ion battery research. Prof. Hui underscored amorphous zinc phosphate's suitability as a material due to its intriguing physical and chemical stability, safety, and cost-effectiveness. He highlighted challenges related to the volume expansion of the anode electrode, the adverse side effects of the interface between the electrolyte and the phosphorus-based anode electrode, and cell-level performance reliability.

To tackle these obstacles, he introduced amorphous zinc phosphate to address significant volume expansion and solid-electrolyte interface instability. Additionally, he proposed the use of non-flammable TEP electrolyte to enhance the safety performance of the batteries. Prof. Hui also shared insights on electrode variations during charging/discharging performance, along with methods for detecting electrochemical impedance resistance. Addressing environmental adaptability at the cell level of black phosphorus anode materials, he demonstrated that amorphous zinc phosphate has a superior physioadsorption property on moisture. He concluded by summarizing his research and outlining future directions to improve the reliability of potassium-ion batteries.

In another research seminar, Prof. Qing Li delivered a talk titled "Building Reliable Aqueous Zinc Batteries." She began by discussing the background and growing significance of aqueous battery research, emphasizing the critical role of zinc as an optimal material due to its excellent balance of kinetics, safety, cost-effectiveness, and energy density. Prof. Li highlighted the pressing reliability challenges faced by aqueous batteries, including issues related to electrolytes, interfaces, anodes, and cell-level performance, which are critical barriers to their practical deployment.

To address these challenges, Prof. Li introduced innovative strategies at multiple levels. At the electrolyte and interface level, she proposed an adhesive hydrogel based on high-concentration electrolytes to mitigate interface slippage and instability, while also exploring co-solvents and artificial SEI layers to regulate double-layer capacitance and enhance battery performance. In the anode section, she presented detailed findings on the differences between electrodes during initial stripping and plating, along with diagnostic methods to identify and mitigate soft short circuits, a key issue impacting battery health and safety. At the cell level, Prof. Li tackled environmental adaptability concerns, particularly in terms of working temperature ranges and calendar aging, proposing specific electrolyte and substrate modifications to improve battery durability. She concluded by summarizing the research works and outlining future directions to further improve the reliability and performance of aqueous zinc batteries, highlighting their immense potential for sustainable energy applications.



❖ Seminars

Prof. Shuang Zhang, Chair Professor and Interim Head of the Department of Physics at the University of Hong Kong, visited IAPME and delivered an invited talk titled "Topological singularities under gauge fields in metamaterials" on 12 December 2024.

Prof. Zhang is a leading physicist in the field of metamaterials and nanophotonics. He is particularly interested in designing artificial photonic structures that can manipulate the propagation of light in ways that go beyond traditional optics. He was the recipient of IUPAP Young Scientist Award in Optics (2010), ERC consolidator grant (2015-2020), Royal Society Wolfson Research Award (2016-2021), and New Cornerstone Investigator program (2023-2028). He was elected OSA fellow in 2016, APS fellow in 2022, and has been on the list of highly cited researchers (by Clarviate) since 2018. During his academic career, Professor Zhang has published more than 200 research papers in peer-reviewed journals, with a total citation close to 48,000 (Google Scholar).

In the presentation, Prof. Zhang shared his recent research work on the topological photonics and metamaterials. After introducing the basic knowledge of topology in physics, he demonstrated various topological singularities, including Weyl points, Dirac points, Yang monopoles, and Berry dipoles, using metamaterials. He then particularly focused on the introduction of their interactions with artificially engineered gauge fields, facilitated by the flexibility in designing metamaterial properties.

❖ Visits

Prof. Zhuo Xiong, Secretary of the Party Committee of the Department of Mechanical Engineering of Tsinghua University, and his delegation visited IAPME on December 16, 2024. During the meeting, Prof. Handong Sun, Associate Director of IAPME, presented an overview of the scientific research developments and talent education initiatives at UM and IAPME. Representing the Department of Mechanical Engineering of Tsinghua University, Prof. Ming Zhou, the Deputy Director of the department, discussed the department's research projects and talent training strategies.

The two parties engaged in a comprehensive exchange of ideas regarding talent development and scientific research, establishing a foundation for future student exchanges and collaborative research efforts. Following the meeting, Prof. Xiong and his delegation visited IAPME's laboratories and exhibition hall, where they expressed high praise for IAPME’s research achievements and their industrial applications.